The Influence of Prescribed Boundary Conditions on Near-Surface Temperature Over the Arctic in the MERRA-2 Atmospheric Model

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Background and Motivation

- The Arctic has warmed more rapidly than anywhere else in the world, but discrepancies exist in near-surface Arctic temperature among modern reanalyses
- Reanalyses include varying treatment of the surface boundary conditions, particularly for sea surface temperature (SST) and sea ice concentration (SIC)
- The Modern Era Retrospective analysis for Research and Applications, version 2 (MERRA-2) exhibits shifts in Arctic temperature throughout the time series (Simmons et al., 2017), hypothesized to be due to changing boundary conditions.

Datasets and Methodology

AMIP-style simulations were performed using the MERRA-2 atmospheric model with a ten member ensemble using MERRA-2 boundary conditions (Gelaro et al., 2017), hereafter called M2AMIP and a five member ensemble using boundary conditions from ERA-Interim (Dee et al., 2011), hereafter referred to as M2AMIPERA.

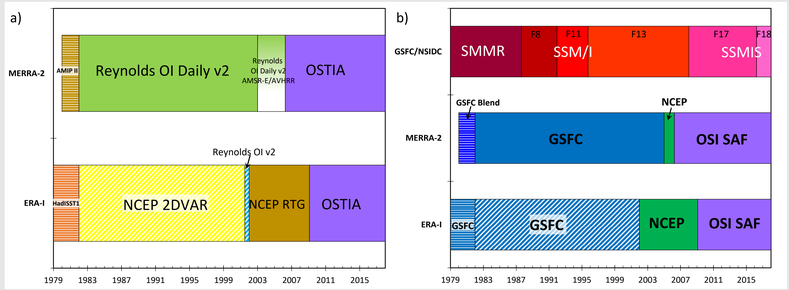

Figure 1: Datasets used to prescribe (a) SST and (b) SIC in MERRA-2 and ERA-I, and therefore the AMIP simulations. Solid boxes indicate daily data, diagonal hatching indicates weekly, and horizontal bars indicate monthly data.

Results: 2 m Temperature over the Arctic Ocean

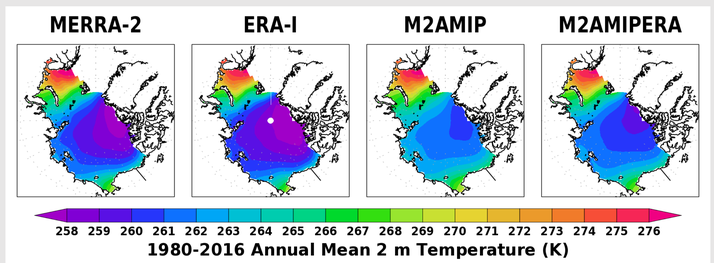

Figure 2: Annual mean 2 m temperature for the period of 1980 through 2016 in a) MERRA-2, b) ERA-I, c) M2AMIP, and d) M2AMIPERA. Points outside the Arctic Ocean are masked and this mask is applied to all figures displaying a time series.

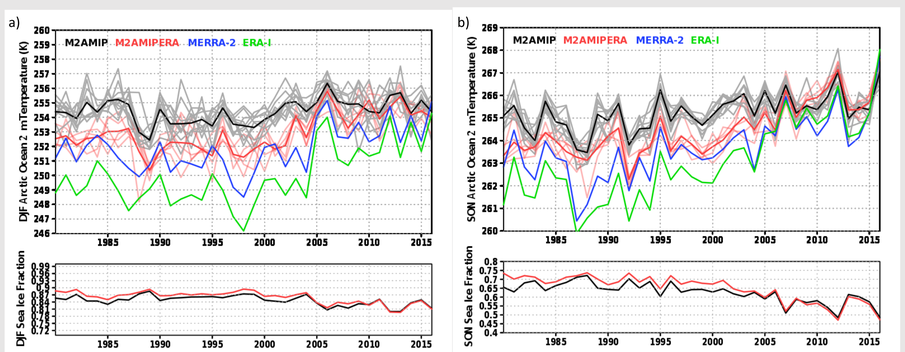

Figure 3: Seasonal mean 2 m temperature over the Arctic Ocean in MERRA-2, ERA-I, M2AMIP, and M2AMIPERA and sea ice fraction from MERRA-2 and ERA-I for a) December-January-February and b) September-October-November

Results: Skin Temperature over Sea Ice

- Skin temperature over sea ice is prognostic; the model calls the turbulence code, followed by the energy budget/radiation scheme to update skin temperature for each time step
- Following ERA-I's switch to OSTIA in 2010, skin temperature over water is nearly identical

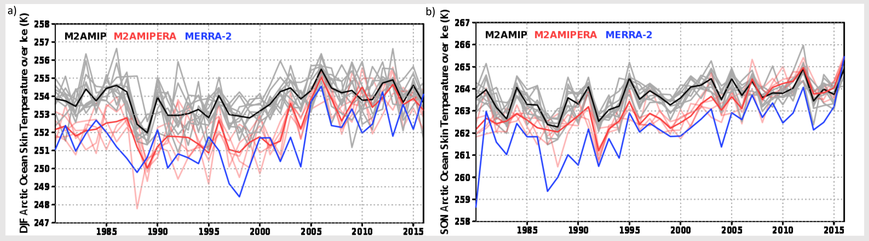

Figure 4: Seasonal mean skin temperature over ice in the Arctic Ocean in MERRA-2, M2AMIP, and M2AMIPERA during a) December-January-February and b) September-October-November

Results: Temperature Tendency Terms and the Impact of Sea Ice

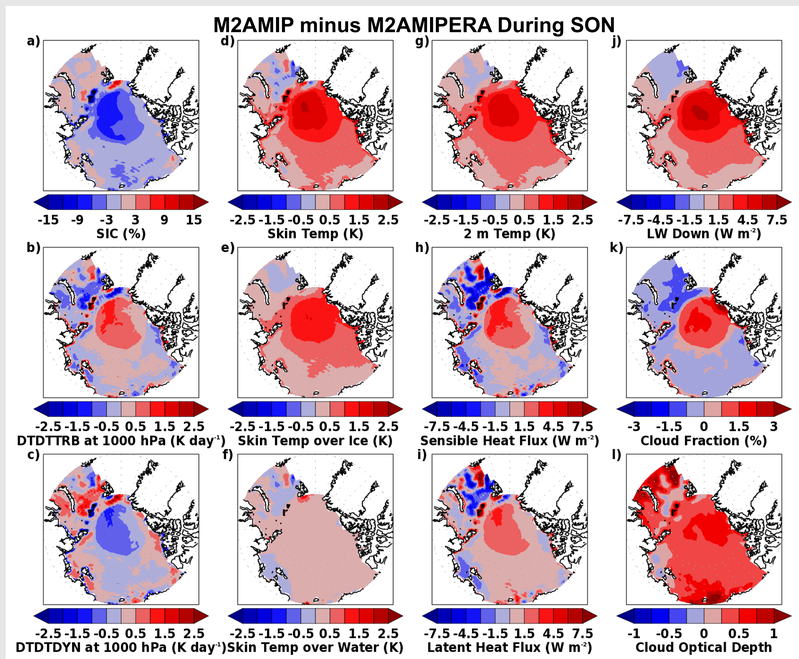

Figure 5: The 1980-2016 mean difference between M2AMIP and M2AMIPERA during SON for a) Sea Ice Concentration, b) temperature tendency due to turbulence at 1000 hPa, c) temperature tendency due to dynamics at 1000 hPA, d) skin temperature, e) skin temperature over ice, f) skin temperature over water, g) 2 m temperature, h) sensible heat flux, i) latent heat flux, j) downwelling longwave radiation, k) cloud fraction, and l) cloud optical depth

- Between 1 January 1989 and 31 January 2009, ERA-I assumes a SIC of 1 anywhere north of 82.5°
- This impacts other fields including 2 m temperature

Conclusions

- MERRA-2 is warm compared to ERA-I in 2 m temperature and this extends to AMIP ensemble simulations using the MERRA-2 atmospheric model
- Seasonal variations exist, with the largest temperature differences occurring during DJF
- Agreement is seen when SST and SIC matches in all datasets; however, when more ice is present in ERA-I, the 2 m temperature and skin temperature over ice are colder
- "Arctic Amplification" occurs in M2AMIPERA, MERRA-2, and ERA-I, but not M2AMIP
- Future Work: Why is M2AMIP so warm prior to the mid 2000s? Why is 2 m temperature in MERRA-2 steady in the late 2000s?

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References:
-Dee, D. P., and Coauthors, 2011: The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. Quart. J. Roy. Meteor. Soc., 137, 553–597, doi:10.1002/qj.828.
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